

UNITED STATES PATENT APPLICATION FOR:

METHOD AND APPARATUS FOR ENCAPSULATION OF  
AN EDGE OF A SUBSTRATE DURING AN ELECTRO-  
CHEMICAL DEPOSITION PROCESS

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## METHOD AND APPARATUS FOR ENCAPSULATION OF AN EDGE OF A SUBSTRATE DURING AN ELECTRO-CHEMICAL DEPOSITION PROCESS

### CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation-in-part of co-pending U.S. patent application Serial No. 09/905,513, filed July 13, 2001 and herein incorporated by reference.

### **BACKGROUND OF THE INVENTION**

#### Field of the Invention

[0002] Embodiments of the invention generally relate to a method and apparatus for electro-chemical deposition of a conductive material on a substrate.

#### Background of the Related Art

[0003] Sub-quarter micron, multi-level metallization is one of the key technologies for the next generation of ultra large scale integration (ULSI). The multilevel interconnects that lie at the heart of this technology require planarization of interconnect features formed in high aspect ratio apertures, including vias, contacts, lines, plugs and other features. Reliable formation of these interconnect features is very important to the success of ULSI and to the continued effort to increase circuit density and quality on individual substrates and die.

[0004] As circuit densities increase, the widths of vias, contacts, lines, plugs and other features, as well as the dielectric materials between them, decrease to less than 250 nanometers, whereas the thickness of the dielectric layers remains substantially constant, with the result that the aspect ratios for the features, *i.e.*, their height divided by width, increases. Due to copper's good electrical performance at such small feature sizes, copper has

become a preferred metal for filling sub-quarter micron, high aspect ratio interconnect features on substrates. However, many traditional deposition processes, such as physical vapor deposition (PVD) and chemical vapor deposition (CVD), have difficulty filling structures with copper material where the aspect ratio exceeds 4:1, and particularly where it exceeds 10:1. As a result of these process limitations, electroplating, which had previously been limited to the fabrication of lines on circuit boards, is now being used to fill vias and contacts on semiconductor devices.

**[0005]** Metal electroplating is generally known and can be achieved by a variety of techniques. A typical method generally comprises deposition of a barrier layer over the feature surfaces, followed by deposition of a conductive metal seed layer, preferably copper, over the barrier layer, and then electroplating a conductive metal over the seed layer to fill the structure/feature. After electroplating, the deposited layers and the dielectric layers are planarized, such as by chemical mechanical polishing, to define a conductive interconnect feature.

**[0006]** While present day electroplating cells achieve acceptable results on larger scale substrates, a number of obstacles impair consistent reliable electroplating onto substrates having micron-sized, high aspect ratio features. Generally, these obstacles include providing uniform power distribution and current density across the substrate plating surface to form a metal layer having uniform thickness and preventing unwanted edge and backside deposition to minimize and control contamination of the substrate being processed as well as subsequent substrates. For example, the electrical contacts between the substrate and the deposition system are often exposed to the plating fluid (e.g., electrolyte) and subsequently become contaminated with deposition material or other contaminants that reduce the contact area between the substrate and contacts. The reduced or irregular contact area disrupts uniform biasing of the substrate that results in non-uniform plating.

**[0007]** Moreover, the position of the contacts relative to the center of the substrate may additionally create non-uniform power distribution over the substrate. Thus, cell tooling for positioning the contacts relative to the

substrate must have tight tolerances to ensure proper centering of the substrates. Tight tolerance requirements are generally undesirable due to the increase in part, assembly and quality assurance costs.

[0008] Therefore, there is a need for an improved electro-chemical deposition system.

#### SUMMARY OF THE INVENTION

[0009] In one aspect of the invention, an electro-chemical deposition apparatus is generally provided. In one embodiment, the apparatus includes an annular conductive body that is adapted to support a substrate and at least one electrical contact pin adapted to electrically bias the substrate. The electrical contact pin has a portion that is brazed into a pin receiving pocket formed in the conductive body.

[0010] In another embodiment, an apparatus for electro-chemical deposition on a substrate includes an annular conductive body having at least one electrical contact pin brazed in a pin receiving pocket formed in a conductive body. A first seal is disposed inward of the electrical contact pin and provides a seal with a conductive body.

[0011] In another embodiment, an apparatus for electro-chemical deposition on a substrate includes an annular conductive body that supports a substrate and is at least partially encapsulated by a dielectric covering. At least one electrical contact pin is brazed to a substrate receiving pocket formed in the conductive body. The contact pin has an exposed portion extending from the conductive body and has a contact surface free of the dielectric covering.

[0012] In another aspect of the invention, a method for fabricating a contact ring utilized for substrate plating includes the steps of inserting a portion of at least one contact pin in a pin receiving pocket formed in an annular conductive body to form an assembly, and brazing the contact pin to the conductive body in a manner that excludes gases between the inserted portion of the contact pin and the pin receiving pocket.

[0013] In another embodiment, a method for fabricating a contact ring

utilized for substrate plating includes the steps of inserting a portion of at least one contact pin in a pin receiving pocket formed in an annular conductive body to form an assembly, brazing the contact pin to the conductive body in a manner that excludes gases between the inserted portion of the contact pin and the pin receiving pocket and shaping an exposed portion of the contact pins to a common elevation relative to the conductive body.

[0014] In yet another embodiment, a method of fabricating a contact ring utilized for substrate plating includes the steps of inserting a portion of at least one contact pin and a pin receiving pocket formed in an annular conductive body to form an assembly, brazing the contact pin to the conductive body in a manner that excludes gases between the inserted portion of the contact pin and the pin receiving pocket, stress relieving the contact pin and the conductive body assembly by holding the assembly at a first temperature, flowing braze between the contact pin and the conductive body by elevating the temperature of the assembly from the first temperature to a second temperature and shaping the exposed portion of the contact pin to a common elevation relative to the conductive body.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0015] So that the manner in which the above recited features and advantages of the invention are attained can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof which are illustrated in the appended drawings.

[0016] It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0017] Fig. 1 is a cross sectional view of an electroplating process cell 400 according to the invention;

[0018] Fig. 2 is a partial cross sectional perspective view of one embodiment of a cathode contact ring;

- [0019] Fig. 3 is a partial sectional view of the cathode contact ring of Fig. 2;
- [0020] Fig. 4 is a partial cross sectional perspective view of one embodiment of a thrust plate;
- [0021] Figs. 5 and 6 are cross sectional views of the cathode contact ring and thrust plate engaging a substrate;
- [0022] Fig. 7 is a partial cross sectional perspective view of another embodiment of a cathode contact ring;
- [0023] Fig. 8 is a partial cross sectional perspective view of a substrate illustrating an exclusion zone relative to a notch;
- [0024] Fig. 9 is a sectional view of the exclusion zone taken along section line 9--9 of Fig. 8.
- [0025] Fig. 10 is a partial cross sectional perspective view of another embodiment of a cathode contact ring;
- [0026] Figs. 11A-B are a partial cross sectional perspective views of alternative embodiments of cathode contact rings;
- [0027] Fig. 12 is a perspective view of one embodiment of a contact strip;
- [0028] Fig. 13 is a perspective view of another embodiment of a contact strip;
- [0029] Fig. 14 is a perspective view of another embodiment of a contact strip; and
- [0030] Fig. 15 is a partial cross sectional perspective view of another embodiment of a cathode contact ring.
- [0031] To facilitate understanding, identical reference numerals have been used, wherever possible, to designate identical elements that are common to the figures.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0032] Fig. 1 is a cross sectional view of an electroplating process cell 100 according to the invention. The processing cell 100 generally comprises a head assembly 110, a process kit 120 and an electrolyte collector 140. Preferably, the electrolyte collector 140 is secured onto the base 142 over an

opening 144 that defines the location for placement of the process kit 120. The electrolyte collector 140 includes an inner wall 146, an outer wall 148 and a bottom 147 connecting the walls 147, 148. An electrolyte outlet 149 is disposed through the bottom 147 of the electrolyte collector 140 and connected to an electrolyte replenishing system 132 through tubes, hoses, pipes or other fluid transfer connectors.

**[0033]** The head assembly 110 is mounted onto a head assembly frame 152. The head assembly frame 152 includes a mounting post 154 and a cantilever arm 156. The mounting post 154 is mounted onto the base 142 of the electroplating process cell 100, and the cantilever arm 156 extends laterally from an upper portion of the mounting post 154. Preferably, the mounting post 154 provides rotational movement with respect to a vertical axis along the mounting post to allow rotation of the head assembly 110. The head assembly 110 is attached to a mounting plate 160 disposed at the distal end of the cantilever arm 156. The lower end of the cantilever arm 156 is connected to a cantilever arm actuator 157, such as a pneumatic cylinder, mounted on the mounting post 154. The cantilever arm actuator 157 provides pivotal movement of the cantilever arm 156 with respect to the joint between the cantilever arm 156 and the mounting post 154. When the cantilever arm actuator 157 is retracted, the cantilever arm 156 moves the head assembly 110 away from the process kit 120 to provide the spacing required to remove and/or replace the process kit 120 from the electroplating process cell 100. When the cantilever arm actuator 157 is extended, the cantilever arm 156 moves the head assembly 110 axially toward the process kit 120 to position the substrate in the head assembly 110 in a processing position.

**[0034]** The head assembly 110 generally comprises a substrate holder assembly 150 and a substrate assembly actuator 158. The substrate assembly actuator 158 is mounted onto the mounting plate 160, and includes a head assembly shaft 162 extending downwardly through the mounting plate 160. The lower end of the head assembly shaft 162 is connected to the substrate holder assembly 150 to position the substrate holder assembly 150 in a processing position and in a substrate loading position.

[0035] The substrate assembly actuator 158 additionally may be configured to provide rotary motion to the head assembly 110. The rotation of the substrate during the electroplating process generally enhances the deposition results. Preferably, the head assembly 110 is rotated between about 2 rpm and about 20 rpm during the electroplating process. The head assembly 110 can also be rotated as the head assembly 100 is lowered to position the substrate in contact with the electrolyte in the process cell as well as when the head assembly 110 is raised to remove the substrate from the electrolyte in the process cell. The head assembly 110 is preferably rotated at a high speed (i.e., > 20 rpm) after the head assembly 110 is lifted from the process cell to enhance removal of residual electrolyte on the head assembly 110 and substrate.

[0036] The substrate holder assembly 150 generally comprises a thrust plate 164 and a cathode contact ring 166 that are suspended from a hanger plate 136. The hanger plate 136 is coupled to the head assembly shaft 162. The cathode contact ring 166 is coupled to the hanger plate 136 by hanger pins 138. The hanger pins 138 allows the cathode contact ring 166 when mated with the weir 178, to move to closer to the hanger plate 136, thus allowing the substrate held by the thrust plate 164 to be sandwiched between the hanger plate 136 and thrust plate 164 for processing.

[0037] Fig. 2 is a cross sectional view of one embodiment of a cathode contact ring 166. In general, the contact ring 166 comprises an annular body having a plurality of conducting members disposed thereon. The annular body is constructed of an insulating material to electrically isolate the plurality of conducting members. Together the body and conducting members form a diametrically interior substrate seating surface which, during processing, supports a substrate and provides a current thereto.

[0038] The contact ring 166 generally comprises a plurality of conducting members 265 at least partially disposed within an annular insulative body 270. The insulative body 270 is shown having a flange 262 and a downward sloping shoulder portion 264 leading to an upper portion 266 of an inner ring surface 268. The insulative body 270 generally comprises a ceramic, plastic



or other substantially rigid, electrically insulating material. For example, the body 270 may be comprised of alumina ( $Al_2O_3$ ), polyvinylidene fluoride (PVDF), perfluoroalkoxy resin (PFA), fluoropolymers like TEFLON®, and TEFZEL®, and similar materials.

**[0039]** The conducting members 265 are defined by a plurality of outer electrical contact pads 280 annularly disposed on the flange 262, a plurality of inner electrical contact pads 272 extending inward from the shoulder 264, and a plurality of embedded conducting connectors 276 which link the pads 272, 280 to one another. The conducting members 265 are isolated from one another by the insulative body 270. The outer contact pads 280 are coupled to a power supply (not shown) to deliver current and voltage to the inner contact pads 272 via the connectors 276 during processing. The inner contact pads 272 supply the current and voltage to a substrate by maintaining contact around a peripheral portion of the substrate. Thus, in operation the conducting members 265 act as discrete current paths electrically connected to a substrate.

**[0040]** The conducting members 265 typically comprise copper (Cu), platinum (Pt), tantalum (Ta), titanium (Ti), gold (Au), silver (Ag), stainless steel or other conducting materials. Alternatively, the conducting members 265 may be comprised of a base material coated with a conducting material. For example, the conducting members 265 may be made of copper base and be coated with platinum. Alternatively, coatings such as tantalum nitride, titanium nitride, rhodium, gold, copper or silver on a conductive base material such as stainless steel, molybdenum, copper and titanium may be used. Optionally, the inner contact pads 272 may comprise a material resistant to oxidation such as platinum, gold, silver or other noble metal. Further, since the contact pads 272, 280 are typically separate units bonded to the conducting connectors 276, the contact pads 272, 280 may each comprise the same or different material while the conducting members 265 one of the same or yet another material. Either or both of the pads 272, 280 and conducting connectors 276 may be coated with a conducting material.

**[0041]** In addition to being a function of the contact material, the total

resistance of each circuit is dependent on the geometry, or shape, of the inner contact pads 272 and the force supplied by the contact ring 166. These factors define a constriction resistance,  $R_{CR}$ , at the interface of the inner contact pads 272 and the inner ring surface 268 due to asperities between the two surfaces. Generally, as the applied force is increased the apparent area is also increased. The apparent area is, in turn, inversely related to  $R_{CR}$  so that an increase in the apparent area results in a decreased  $R_{CR}$ . Thus, to minimize overall resistance it is preferable to maximize force. The maximum force applied in operation is limited by the yield strength of a substrate which may be damaged under excessive force and resulting pressure. However, because pressure is related to both force and area, the maximum sustainable force is also dependent on the geometry of the inner contact pads 272. Thus, while the contact pads 272 may have a flat upper surface as in Fig. 2, other shapes may be used to advantage. For example, knife-edge and hemispherical contact pads may be utilized. A person skilled in the art will readily recognize other shapes that may be used to advantage. A more complete discussion of the relation between contact geometry, force, and resistance is given in *Ney Contact Manual*, by Kenneth E. Pitney, The J. M. Ney Company, 1973, which is hereby incorporated by reference in its entirety.

**[0042]** The number of connectors 276 may be varied depending on the particular number and size of contact pads 272 desired. For example, a contact ring 166 configured to process a 200mm substrate may include up to 36 contact pads 272 spaced equally around the ring. However, more or a single contact pad 272 which may circumscribe the contact ring 166 may also be utilized.

**[0043]** Fig. 3 depicts a sectional view of one embodiment of a contact ring 166 illustrating the inner contact pad 272 extending inward from the shoulder 264. Generally, the contact ring 166 includes a support flange 302 that extends radially inward from the shoulder 264 below the inner contact pads 272 to a lower portion of the inner ring surface 268. The support flange 302 supports the inner contact pad 272 and maintains planarity of a contact surface 304 of the inner contact pad 272 while the substrate is seated thereon

during processing. Additionally, the support flange 302 includes a recess 308 disposed on a bottom surface 306 and/or inner ring surface 268 of the contact ring 166.

**[0044]** The recess 308 is configured to accept a clamp ring 310 that retains a first seal 318 to the contact ring 166. The clamp ring 310 may be an integral part of the contact ring 166, or be comprised of a material compatible with the plating fluid. In one embodiment, the clamp ring 310 is fastened to the contact ring 166 by a plurality of screws 312 threaded into a threaded hole 314 in the insulative body 270. The clamp ring 310 includes an upturned member 316 that defines a seal-receiving groove 330 between the upturned member 316 and the support flange 302.

**[0045]** The first seal 318 generally is configured to provide a fluid seal between the body 270 of the contact ring 166 and the substrate when the substrate is disposed on the inner contact pad 272 (see line 332). The first seal 318 is generally comprised of a material compatible with the plating fluid and having a durometer that effectively seals against the substrate without stressing or damaging the substrate's surface. An example of one suitable seal material is ethylene propylene diene terpolymer (EPDM).

**[0046]** The first seal 318 may include a variety sealing means such as gaskets, o-rings, lip seals, cup seals, lobed rings and other types of fluid seals. The first seal 318 may include a variety of profiles, including circular, square, lip-seals or other shapes. In one embodiment, the first seal 318 includes a base 322 having a lip 324 extending therefrom. The base 322 is generally annular in form and is configured to be retained by the seal-receiving groove 330. Optionally, an undercut 320 may be disposed in the support flange 302. The base 322 of the first seal 318 may be configured with a diameter that interfaces with the undercut 320 formed in the support flange 302 to secure the seal 318 to the flange 302. The lip 324 includes a first sealing surface 326 and a second sealing surface 328. The first sealing surface 326 is generally disposed on the lip 324 opposite the base 322 and provides a seal between the substrate and the first seal 318. The second sealing surface 328 is generally disposed on the radially outer portion of the

lip 324 and contacts the inner contact pad 272 and/or the inner ring surface 268 of the support flange 302 when the lip 324 is compressed to line 332 by the substrate seated on the contact pad 272. Additionally or in the alternative, the base 322 may provide a seal between the first seal 318 and insulative body 270.

**[0047]** The lip 324 of the first seal 318, in a non-compressed or "free" state, generally extends radially inward of the base 322. The lip 324 extends from the base 322 and tapers to the first sealing surface 326. The shape of the first seal 318 generally allows the lip 324 to move radially inwards when compressed and to return to its original configuration relative to the base 322 as the force upon the seal 318 is removed as further described below.

**[0048]** The inner ring surface 268 and the contact surface 304 of the inner contact pad 272 generally define a substrate receiving pocket 240. The receiving pocket 240 is generally configured to locate the surface relative to the contact ring 166 and assure the entire perimeter of the substrate make electrical contact with the contact ring 166 during processing.

**[0049]** Fig. 4 depicts one embodiment of the thrust plate 164. The thrust plate 164 is generally cylindrical in form and includes a top surface 402 and a bottom surface 404. The thrust plate 164 is generally comprised or coated with a material compatible with the plating fluid.

**[0050]** A perimeter 406 of the thrust plate 162 generally includes a groove or notch 408 that is adapted to receive a second seal 410. The second seal 410 generally provides a fluid seal between the thrust plate 162 and the flange 262 of the contact ring 166. The second seal 410 may include a variety sealing means such as gaskets, o-rings, lip seals, cup seals, lobed rings and other types of fluid seals, and may have a variety of profiles, including circular, square, lip-seals or other shapes. The second seal 410 is generally comprised of a material compatible with the plating fluid and has a durometer that effectively seals against the contact ring 166. An example of one suitable seal material is ethylene propylene diene terpolymer (EDPM).

**[0051]** In the embodiment depicted in Fig. 4, the second seal 410 includes a base 412 and a lip 414. The base 412 is generally disposed in the

notch 408. The lip 414 typically extends from the base 412 downwards and radially outwards. The lip 414 is configured to seal against the flange 262 of the contact ring 166 and, as such, is disposed radially outward of the intersection of the flange 262 and shoulder 264 of the contact ring 166. Generally, the second seal 410 is configured similar to the first seal 318.

**[0052]** The bottom 404 of the thrust plate 164 generally includes a port 416 and a groove or notch 418. The port 416 is coupled to a fitting 420 disposed in the top surface 402 of the thrust plate 164. The fitting 420 is coupled by a supply tube 424 to a fluid source (not shown) that supplies pressure or vacuum to retain and dechuck the substrate from the bottom surface 404 of the thrust plate 164.

**[0053]** The notch 418 is generally adapted to receive a third seal 422. The third seal 422 is adapted to contact the substrate to facilitate vacuum chucking of the substrate. The third seal 422 generally extends beyond the bottom 404 in its un-compressed state and it typically comprises of a material compatible with the plating fluid and of a durometer that promotes sealing with the substrate while minimizing stress and damage to the substrate. The third seal 422 may include a variety sealing means such as gaskets, o-rings, lip seals, cup seals, lobed rings and other types of fluid seals. The profile of the third seal 422 may vary as discussed relative to the first and second seals 318, 410.

**[0054]** In the embodiment depicted in Fig. 4, the third seal 422 includes a base 426 and a lip 428. The base 426 is generally disposed in the notch 418. The lip 428, in a non-compressed or "free" state, typically extends from the base 426 downwards and radially outwards. The lip 428 is configured to seal against the substrate inward of the edge of the substrate or locating indicia (*i.e.*, flat or notch disposed therein) to prevent plating fluid from entering the region between the seals 410, 422 and contacting and contaminating the inner contact pads 272 (see Figs. 5 and 6). Typically, the lip 428 is configured to contact the substrate radially outward of the contact surface 320 of the inner contact pad. Generally, the third seal 422 is configured similar to the first seal 318 and/or second seal 410.

[0055] Figs. 5 and 6 depict the head assembly 110 in one mode of operation. Referring to Fig. 5, a substrate 502 is disposed adjacent the thrust plate 164 and in contact with the third seal 422. At least a partial vacuum is drawn in a plenum 504 defined between the thrust plate 164 and substrate 502 to chuck or retain the substrate to the thrust plate 164. The head assembly 110 is moved towards the contact ring 166. As the substrate 502 nears the contact ring 166, the substrate sealingly contacts the lip 324 of the first seal 318 at the first sealing surface 326. The first seal 318 is deformed as the substrate 502 moves closer to the contact pads 272 disposed on the contact ring 166. The deformation of the first seal 318 causes the lip 324 to move downward and outward. The outward movement of the lip 324 causes a second sealing surface 328 to sealingly contact the inner diameter of the flange 302.

[0056] As the thrust plate 164 continues to move towards the contact ring 166, the second seal 410 sealingly engages the contact plate 166 as shown in Fig. 6. The substrate is now sandwiched between the first seal 318 and third seal 422 which respectively define inner boundaries of an exclusion zone 604. The second seal 410 defines an outer boundary of the exclusion zone 604. Thus, as the plating fluid is disposed on the plating surface 602 of the substrate 502, an edge 606 of the substrate 502 which is encapsulated by the exclusion zone 604 is isolated from contact with the plating fluid. As the contact pads 272 are disposed within the exclusion zone 604, contamination of the contact pads 272 by the plating fluid and deposition build-up thereon is substantially eliminated, thus extending plating uniformity and extending the service life of the contact ring 166. Additionally, the compression of first seal 318 assists in releasing the substrate from the contact ring 166 after deposition.

[0057] Fig. 7 depicts another embodiment of a contact ring 700. Generally, the contact ring 700 is comprised of a conductive body 702 that is at least partially encapsulated by an insulating covering 704. The conductive body 702 is typically a metal such as copper, stainless steel, aluminum or other metal. The insulating covering 704 is typically a ceramic or plastic, for

example, fluoropolymers, polyethylene or polyimide.

**[0058]** Generally, the conductive body 702 includes a top surface 760, a bottom surface 762, an outer diameter 764 and an inner diameter 766. The top surface 760 includes a flange 710 and a substrate seating surface 714 coupled between a shoulder 712. The shoulder 712 is generally disposed at an acute angle relative to the centerline of the contact ring 700 to center the substrate relative to the contact ring 700. Optionally, the substrate seating surface 714 may be recessed from the shoulder 712 to form a substrate receiving pocket 716. The substrate receiving pocket 716 generally includes a cylindrical wall 718 having a diameter configured slightly larger than the substrate (see Figs. 9 and 10) so that a first seal, coupled to the contact ring 700, remains in sealing contact with the substrate even in conditions where a substrate 800 is located to one side of the pocket 716 such that a flat or notch 802 of the substrate 800 is biased towards a centerline 804 of the ring 700.

**[0059]** Referring back to Fig. 7, the contact ring 700 generally includes one or more electrical contact pads 720. The electrical contact pads 720 generally comprise a portion of the conductive body 702 that extends from the substrate seating surface 714. The electrical contact pads 720 are typically formed by removing a portion of the insulative covering 704 on the substrate seating surface 714. Optionally, the covering 704 may be removed from the additional portions of the substrate seating surface 714 or other portions of the contact ring 700. The exposed conductive body 702 may be machined to form a single contact pad 720 shown as a ring 722 circumscribing the substrate seating surface 714.

**[0060]** Alternatively, as depicted in Fig. 10, the electrical contact pads 720 may be configured as a plurality of contacts 1010, such as segmented arcs, hemispherical contacts or other shapes. Other methods of fabrication may alternatively be utilized, for example, pre-forming the contacts pads 720 in the conductive body 702, then masking the pads 720 before applying the insulative covering 704 to leave the pads 720 exposed, or removing the covering 704 only from the pads 720 after application of the coating 704 among other methods.

[0061] Power is generally supplied to the substrate through the electric contact pads 720 through one or more terminals 724 coupled to the body 702 through the insulative covering 704. The terminals 724 are typically coupled to a power source (not shown).

[0062] Additionally, depicted in Fig. 9 is a substrate wiping action of the first seal 318 which keeps plating fluids from contaminating the contact pads 720. Generally, as the substrate 800 is moved away from the contact ring 700, the lip 324 of the first seal 318 moves radially inwards (*i.e.*, towards the centerline 804) as the compression of the seal 318 is removed. As the lip 324 moves inward, the first sealing surface 326 moves across a feature side 902 of the substrate 800, wiping the plating fluid away from the contact pads 720 as the substrate 800 is removed from the contact ring 700. The wiping action of the lip 324 substantially prevents plating fluid from dipping or otherwise contaminating the contact pads 720 which may adversely affect the plating of subsequent substrates.

[0063] Referring back to Fig. 1, the process kit 120 is generally positioned below the substrate holder assembly 150. The process kit 120 generally comprises a bowl 130, a container body 172, an anode assembly 174 and a filter 176. Preferably, the anode assembly 174 is disposed below the container body 172 and attached to a lower portion of the container body 172, and the filter 176 is disposed between the anode assembly 174 and the container body 172. The container body 172 is preferably a cylindrical body comprised of an electrically insulative material, such as ceramics, plastics, plexiglass (acrylic), lexane, PVC, CPVC or PVDF. Alternatively, the container body 172 can be made from a metal, such as stainless steel, nickel or titanium, which is coated with an insulating layer, such as Teflon®, PVDF, plastic, rubber and other combinations of materials that do not dissolve in the electrolyte and can be electrically insulated from the electrodes (*i.e.*, the anode and cathode of the electroplating system). The container body 172 is preferably sized and adapted to conform to the substrate plating surface and the shape of the substrate being processed through the system, typically circular or rectangular in shape. One preferred embodiment of the container



body 172 comprises a cylindrical ceramic tube having an inner diameter that has about the same dimension as or slightly larger than the substrate diameter. The inventors have discovered that the rotational movement typically required in typical electroplating systems is not required to achieve uniform plating results when the size of the container body conforms to about the size of the substrate plating surface.

**[0064]** An upper portion of the container body 172 extends radially outward to form an annular weir 178. The weir 178 extends over the inner wall 146 of the electrolyte collector 140 and allows the electrolyte to flow into the electrolyte collector 140. The upper surface of the weir 178 preferably matches the lower surface of the cathode contact ring 166. Preferably, the upper surface of the weir 178 includes an inner annular flat portion 180, a middle inclined portion 182 and an outer declined portion 184. When a substrate is positioned in the processing position, the substrate plating surface is positioned above the cylindrical opening of the container body 172, and a gap for electrolyte flow is formed between the lower surface of the cathode contact ring 166 and the upper surface of the weir 178. The lower surface of the cathode contact ring 166 is disposed above the inner flat portion 180 and the middle inclined portion of the weir 178. The outer declined portion 184 is sloped downwardly to facilitate flow of the electrolyte into the electrolyte collector 140.

**[0065]** A lower portion of the container body 172 extends radially outward to form a lower annular flange 186 for securing the container body 172 to the bowl 130. The outer dimension (*i.e.*, circumference) of the annular flange 186 is smaller than the dimensions of the opening 144 and the inner circumference of the electrolyte collector 140 to allow removal and replacement of the process kit 120 from the electroplating process cell 100. Preferably, a plurality of bolts 188 are fixedly disposed on the annular flange 186 and extend downwardly through matching bolt holes on the bowl 130. A plurality of removable fastener nuts 190 secure the process kit 120 onto the bowl 130. A seal 187, such as an elastomer O-ring, is disposed between container body 172 and the bowl 130 radially inward from the bolts 188 to

prevent leaks from the process kit 120. The nuts/bolts combination facilitates fast and easy removal and replacement of the components of the process kit 120 during maintenance.

**[0066]** Preferably, the filter 176 is attached to and completely covers the lower opening of the container body 172, and the anode assembly 174 is disposed below the filter 176. A spacer 192 is disposed between the filter 176 and the anode assembly 174. Preferably, the filter 176, the spacer 192, and the anode assembly 174 are fastened to a lower surface of the container body 172 using removable fasteners, such as screws and/or bolts. Alternatively, the filter 176, the spacer 192, and the anode assembly 174 are removably secured to the bowl 130.

**[0067]** The anode assembly 174 preferably comprises a consumable anode that serves as a metal source in the electrolyte. Alternatively, the anode assembly 174 comprises a non-consumable anode, and the metal to be electroplated is supplied within the electrolyte from the electrolyte replenishing system 132. The anode assembly 174 may be a self-enclosed module having a porous anode enclosure 194 preferably made of the same metal as the metal to be electroplated, such as copper. Alternatively, the anode enclosure 194 is made of porous materials, such as ceramics or polymeric membranes. A soluble metal 196, such as high purity copper for electro-chemical deposition of copper, is disposed within the anode enclosure 194. The soluble metal 196 preferably comprises metal particles, wires or a perforated sheet. The porous anode enclosure 194 also acts as a filter that keeps the particulates generated by the dissolving metal within the anode enclosure 194. As compared to a non-consumable anode, the consumable (*i.e.*, soluble) anode provides gas-generation-free electrolyte and minimizes the need to constantly replenish the metal in the electrolyte.

**[0068]** An anode electrode contact 198 is inserted through the anode enclosure 194 to provide electrical connection to the soluble metal 196 from a power supply. Preferably, the anode electrode contact 198 is made from a conductive material that is insoluble in the electrolyte, such as titanium, platinum and platinum-coated stainless steel. The anode electrode contact

198 extends through the bowl 130 and is connected to an electrical power supply. Preferably, the anode electrical contact 198 includes a threaded portion 197 for a fastener nut 199 to secure the anode electrical contact 198 to the bowl 130, and a seal 195, such as an elastomer washer, is disposed between the fastener nut 199 and the bowl 130 to prevent leaks from the process kit 120.

**[0069]** The bowl 130 generally comprises a cylindrical portion 102 and a bottom portion 104. An upper annular flange 106 extends radially outward from the top of the cylindrical portion 102. The upper annular flange 106 includes a plurality of holes 108 that matches the number of bolts 188 from the lower annular flange 186 of the container body 172. To secure the upper annular flange 106 of the bowl 130 and the lower annular flange 186 of the container body 172, the bolts 188 are inserted through the holes 108, and the fastener nuts 190 are fastened onto the bolts 188. Preferably, the outer dimension (*i.e.*, circumference) of the upper annular flange 106 is about the same as the outer dimension (*i.e.*, circumference) of the lower annular flange 186. Preferably, the lower surface of the upper annular flange 106 of the bowl 130 rests on a support flange of the electroplating process cell 100 when the process kit 120 is positioned thereon.

**[0070]** The inner circumference of the cylindrical portion 102 accommodates the anode assembly 174 and the filter 176. Preferably, the outer dimensions of the filter 176 and the anode assembly 174 are slightly smaller than the inner dimension of the cylindrical portion 102 to force a substantial portion of the electrolyte to flow through the anode assembly 174 first before flowing through the filter 176. The bottom portion 104 of the bowl 130 includes an electrolyte inlet 134 that connects to an electrolyte supply line from the electrolyte replenishing system 132. Preferably, the anode assembly 174 is disposed about a middle portion of the cylindrical portion 102 of the bowl 130 to provide a gap for electrolyte flow between the anode assembly 174 and the electrolyte inlet 134 on the bottom portion 104.

**[0071]** The electrolyte inlet 134 and the electrolyte supply line are preferably connected by a releasable connector that facilitates easy removal

and replacement of the process kit 120. When the process kit 120 needs maintenance, the electrolyte is drained from the process kit 120, and the electrolyte flow in the electrolyte supply line is discontinued and drained. The connector for the electrolyte supply line is released from the electrolyte inlet 134, and the electrical connection to the anode assembly 174 is also disconnected. The head assembly 110 may be raised or rotated to provide clearance for removal or service of the process kit 120.

**[0072]** Fig. 11A depicts another embodiment of a contact ring 1100. Generally, the contact ring 1100 is comprised of a conductive body 1102 and at least one contact pin 1104. The conductive body 1102 is typically a metal such as copper, stainless steel, aluminum or other metal. Generally, the conductive body 1102 includes a top surface 1160, a bottom surface 1162, an outer diameter 1164 and an inner diameter 1166. An electrical lead 1024 is coupled to the conductive body 1102, typically through a flange 1010 comprising the outer portion of the top surface 1160. The top surface 1160 also includes a substrate seating surface 1114 coupled between a shoulder 1112 and the inner diameter 1166. The shoulder 1112 is generally disposed at an acute angle relative to the centerline of the contact ring 1100. Optionally, the substrate seating surface 1114 may be recessed from the shoulder 1112 to form a substrate receiving pocket 1116. The substrate receiving pocket 1116 generally includes a cylindrical wall 1118 having a diameter configured slightly larger than the substrate (see Figs. 9 and 11 and the discussion relative to contact ring 700) so that a first seal 1150, coupled to the contact ring 1100 proximate the inner diameter 1166, remains in sealing contact with the substrate (not shown in Fig. 11A).

**[0073]** The substrate seating surface 1114 includes at least one pin receiving pocket (e.g., slot 1152) formed therein which receives the contact pin 1104. The contact pin 1104 is typically comprised of a conductive material that provides good electrical contact with the substrate during processing. In one embodiment, the contact pin 1104 is typically fabricated from a conductive material such as platinum or platinum alloys.

**[0074]** The contact pin 1104 may be a single ring or be comprised of a

plurality of individual segments as shown in Fig. 11B. The contact pin 1104 is typically coupled to the conductive body 1102 in a manner that ensures good electrical contact while providing good dimensional stability over time. For example, the conductive pin 1104 may be fixed to the conductive body 1102 using conductive adhesives or by brazing. In one embodiment depicted in Fig. 11A, the conductive body 1102 is fixed to the conductive body 1102 by a noble metal braze 1154. The braze 1154 generally wets the adjacent surfaces of the conductive body 1102 and contact pin 1104 thereby eliminating or displacing any air or gas bubbles that may be present between the adjoining surfaces. Additionally, brazing allows for a repeatable, controlled conductance along the circumference of the contact pin 1104 thereby promoting uniform current flow along the entire contact area of the contact ring to the substrate resulting in good plating uniformity and performance.

**[0075]** The braze 1154 is generally applied by a process 1200 that simplifies fabrication over conventionally constructed contact rings. Referring both to Fig. 11A and the flow diagram of Fig. 12, the process 1200 begins with press-fitting or otherwise inserting the contact pin 1104 into the slot 1152 of the conductive body 1102 at step 1202. At step 1204, the braze 1154 is applied the conductive body 1102 and contact pin 1104. At step 1206, the assembly (contact pin 1104 and conductive body 1102) is heated to about 550 to about 600 degrees Celsius to stress relieve the contact ring 1100. Typically, the stress relieving step 1206 has a duration of about 20 to about 60 minutes, however, the temperature and time for the stress relieving step will vary according to the material of the body 1102. After the stress relieving step 1206, a braze flow step 1208 is initiated by heating the assembly to about 1200 degrees Celsius or other temperature that flows the braze 1154 uniformly between the conductive body 1102 and contact pin 1104 to fill all voids and remove any trapped gas. As the braze 1154 completely fills the interstitial gap between the conductive body 1102 and the contact pin 1104, good electrical contact between the conductive body 1102 and the contact pin 1104 is ensured and the possibility of degradation of electrical contact due to thermal expansion of gases between the conductive body 1102 and the

contact pin 1104 during processing is substantially eliminated.

**[0076]** Optionally, the contact ring 1100 may be at least partially coated with a ceramic or plastic insulating covering 1168, for example, a fluoropolymer, polyethylene or polyimide or other dielectric compatible with the plating process. The insulating covering 1168, applied in step 1210, may be applied by various methods, for example, spraying.

**[0077]** In step 1212, an exposed portion 1170 of the contact pin 1104 that extends from the conductive body 1102 is shaped to remove any run-out in elevation existing between the contact pin 1104 and the conductive body 1102. The shaping step 1212 may include machining, grinding, pressing, cutting or other processes that promotes surface planarity or common elevation of the exposed portion 1170 of the pin 1104. The shaping step 1212 may be configured to leave a single, annular substrate contact surface on the exposed portion, or may be configured to provide a number of co-planar contact points, for example, a saw tooth configuration. The exposed portion 1170 is machined to provide a contact geometry that provides good electrical contact between the contact pin 1104 and the substrate seated thereon. Moreover, the machining the exposed portion 1170 of the contact pin 1104 to a common elevation relative to and along the conductive body 1102 ensures uniform loading of the substrate on the contact pins 1104 that results in uniform current flux through the contact pins 1104 to the substrate along each contact point (i.e., point where the substrate is in physical contact with the contact pin 1164). Uniform current flux enhances plating uniformity on the substrate. Additionally, if the exposed portion 1170 is encapsulated by the covering 1168 applied in step 1210, the covering 1168 is removed to allow intimate contact between the contact pin 1104 and the substrate during processing. Alternatively, the exposed portion 1170 may be shaped prior to applying the covering 1168 to the conductive body 1102, with the exposed portion 1170 being masked during the application of the covering 1170 to prevent electrically insulating the exposed portion 1170.

**[0078]** Fig. 11B depict another embodiment of a contact ring 1180. The contact ring 1180 is generally similar to the ring 1100 described above, except

wherein the ring 1180 has contact pins 1182 (three are shown) disposed proximate an inner diameter 1184 while not having a first seal (1150 in Fig. 11A). The contact pins 1182, which may be a plurality of discrete elements as shown in Fig. 11B or a continuous annular ring, is coupled to a conductive body 1186 of the contact ring 1180 by a braze 1188 applied between the conductive body 1186 and a portion of the pins 1182 disposed in a slot 1190 formed in the conductive body 1186, typically fixed thereto by brazing. The contact pins 1182 and an optional covering 1192 are generally applied by the method described by process 1200.

**[0079]** Fig. 13 depicts another embodiment of a contact pin 1302. The contact pin 1302 is generally configured as a plurality of arc segments or sections of a ring. To ensure uniform electrical contact around the substrate, a plurality of contact pins 1302 (only one is shown in Fig. 13) are typically arranged in a polar array and disposed in the slot 1160. The contact pin 1302 includes at least one tooth 1304 (two are shown) that extends above a body 1306. The body 1306 is generally inserted into the slot 1160 as described with reference to the embodiments of Figs. 11A-B, with the teeth 1304 extending above the substrate seating surface 1114 of the conductive body 1102 (shown in phantom). The contact pin 1302 is generally fixed to the conductive body 1102 as described in method 1100, including the application of an optional dielectric coating to the conductive body 1102.

**[0080]** Fig. 14 depicts another embodiment of a contact pin 1402. The contact pin 1402 is generally configured as an arc or section of a ring but may alternatively be a ring. The contact pin 1402 includes a plurality of contact posts 1404 (three are shown) that are inserted into a hole 1408 formed in a body 1406 of the pin 1402. The body 1406 is generally inserted into the slot 1160 as described above with the posts 1404 extending above the substrate seating surface 1114 of the conductive body 1102 (shown in phantom). The posts 1404 are typically brazed to the body 1406 prior to inserting the contact pin 1406 into the slot 1152. Alternatively, the posts 1404 may be inserted and brazed into the holes 1408 of the contact pin 1402 as part of any step of the method 1100 utilized to fix the body 1406 to the conductive body 1102.

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**[0081]** Fig. 15 depicts another embodiment of a contact ring 1500. Generally, the contact ring 1500 is comprised of a conductive body 1502 and a plurality of contact pins 1504. The conductive body 1502 is typically a metal such as copper, stainless steel, aluminum or other metal. Generally, the conductive body 1502 includes a top surface 1560, a bottom surface 1562, an outer diameter 1564 and an inner diameter 1566. The top surface 1560 includes a flange 1510 and a substrate seating surface 1514 coupled between a shoulder 1512 and the inner diameter 1566. The shoulder 1512 is generally disposed at an acute angle relative to the centerline of the contact ring 1500 to center the substrate relative to the contact ring 1500. Optionally, the substrate seating surface 1514 may be recessed from the shoulder 1512 to form a substrate receiving pocket 1516 as described with reference to the pocket 1116 described above.

**[0082]** The substrate seating surface 1514 includes a plurality of apertures 1552 formed therein. Each of the apertures 1552 receives a portion of a respective contact pin 1504. The contact pin 1504 is typically comprised of a conductive material that provides good electrical contact with the substrate during processing, for example, platinum or platinum alloys.

**[0083]** The contact pin 1504 is typically coupled to the conductive body 1502 in a manner that ensures good electrical contact while providing good dimensional stability over time. For example, the conductive pin 1504 may be fixed to the conductive body 1502 using conductive adhesives or by brazing. In the embodiment depicted in Fig. 15, the conductive body 1502 is fixed to the conductive body 1502 by a noble metal braze 1554 in a method similar to the method 1100 described above.

**[0084]** While the foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof. The scope of the invention is determined by the claims which follow.